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RESPONSE OF WALLEYE (*Stizostedion vitreum*) TO SOUND

Report No 90-122-K

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ABSTRACT

The objectives of this study were to determine the behavioural response of walleye (*Stizostedion vitreum*) to two types of impulsive sounds produced by a SKRAM Fishpulser and determine if individuals habituate to these stimuli. Results indicated that individuals were repelled by the projected test sounds but the effectiveness differed according to the frequency spectrum. Results indicated that walleye did not habituate to either sound during an exposure of two hours. A simultaneous comparison between sound and a second deterrent, light, showed sound to be more effective in repelling walleye.

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EXECUTIVE SUMMARY

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The objectives of this study were to determine the behavioural response of walleye (*Stizostedion vitreum*) to two types of impulsive sounds produced by a SKRAM Fishpulser and determine if individuals habituate to these stimuli.

A systematic experimental design was adopted where a control period (Fishpulser not operating) was immediately followed by an experimental period (Fishpulser operating). Two differently tuned faceplates were used on the SKRAM Fishpulser to generate sounds of two different frequencies. Short term tests during which the Fishpulser operated for five minutes, were conducted to determine the initial response of walleye to each sound. Individual tests were separated by a 55-min rest period (no Fishpulser operating) to allow for the re-distribution of walleye in the corridor. At the end of a 5-min test period, the number of individuals within zone 1 (first 5 m from the Fishpulser) was tabulated and compared to the number of fish in the remaining two zones 2 and 3. This procedure was used for both sounds. The distribution of the fish was monitored using a video camera.

Long term tests were conducted to determine whether the test individuals eventually habituate to the signal generated from the Fishpulser. These tests followed the completion of each of the respective short term tests and involved the same individuals.

Long term tests involved operating the Fishpulser continuously for two hours. The distribution was monitored using a video camera. The distribution during the experimental phase was compared to a similar control phase (Fishpulser not operating).

Sound pressure levels produced by the Fishpulser were measured and analyzed to determine the acoustical properties presented to the fish.

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Additional tests were conducted to contrast sound to a known repellant-light. The effectiveness of either sound or light was simultaneously compared by operating the Fishpulser in one zone while illuminating another zone with an incandescent light.

Results indicated that individuals were repelled by the projected test sounds but the effectiveness differed according to the frequency spectrum. Results also indicated that walleye did not habituate to either the first or second projected frequency spectrum for two hours. A simultaneous comparison between sound and a second deterrent, light, showed sound to be more effective in repelling walleye.

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RESPONSE OF WALLEYE (*Stizostedion vitreum*) TO SOUND

1.0 INTRODUCTION

Protection schemes for fish stocks at controlled sites or areas have generally either involved the use of mechanical or behavioral means of handling fish. Mechanical systems attempt to physically exclude fish and have proven effective in some instances. Nevertheless, these systems are costly to install, maintain, and operate and may contribute to fish mortality through handling. Behavioural systems are less expensive and since these systems rely on the innate responses of fish to controlled stimuli (*i.e.* visual or audio), do not require any direct physical handling of the fish.

The use of sound as a management tool to control the movement of fish to and from specific areas has received considerable attention in recent years (Haymes and Patrick 1986, McKinley and Patrick 1986, 87, 88, Patrick, 1987, and McKinley, 1989). These studies have shown that high amplitude, low frequency sound, has proven effective in excluding certain species of fish. A species specific response to sound is expected since hearing ability among fishes has been shown to be dissimilar (Tavolga 1980).

Since water is an effective transmitter of sound, a sonic signal can be perceived by fish at a considerable distance from the source. If deployed correctly, sound can serve as a cost effective behavioral deterrent or attractant for fish.

The objectives of this study were to: 1) determine the response of walleye (*Stizostedion vitreum*) to two low frequency, high amplitude impulsive sound signals and 2) determine if walleye habituate to these acoustic signals.

2.0 METHODS AND MATERIALS

2.1 Test Species

Sixty-four adult walleye (*Stizostedion vitreum*) were collected by angling in the intake-forebay of BNGS. The size of the walleye collected ranged from approximately 300 to 450 mm. This ensured that mature walleye were examined (*i.e.* - males generally mature over 279 mm and females at 356-432 mm, Scott and Crossman, 1973). These fish were allowed to acclimate to the test temperature for at least one week prior to any experimentation. Mortality averaged less than 1%.

2.2 Experimental Device

A specially designed fish repelling sound source was used for this study. This was a SKRAM Fishpulser unit produced by FMC of Canada. The Fishpulser is an electromechanical transducer which produces impulsive type sound in water of approximately 220 dB peak at 1 m. The frequency spectrum of the sound is determined by an acoustic coupling plate which is tuned for generating sound in the range of 50-20,000 Hz which fish can sense. Two differently tuned plates were used in this investigation which were designated by their thicknesses as Plate 1 (0.9 cm) and plate 2 (0.7 cm). The Fishpulser was submerged in the tank to a depth of 0.9 m (water surface to plate center) and operated at approximately 20 pulses per minute.

2.3 Experimental Tank

Experiments were conducted in a square, semi-anechoic tank (approximately 15.5 m x 15.5 m x 1.5 m in depth). The water was 1.3 m deep. The tank was divided equally in two by a cement block wall which allowed for the employment of a paired control/experimental design and to minimize sound transmissions. The Fishpulser was placed in one of the outside corners of the tank. *Dummy* Fishpulsers (submerged steel drums) were placed in all remaining corners to remove any visual reference to the real Fishpulser. Video cameras were positioned over the real and one *dummy* Fishpulser to monitor fish distribution in the experimental (real Fishpulser) and control (*dummy* Fishpulser) halves of the tank.

2.4 Experimental Design

Due to the tendency of walleye to position themselves along the walls and bottom of the tank, the initial paired experimental/control design was modified to ensure an adequate evaluation of the response of walleye to sound. A systematic experimental design was adopted where a control period (Fishpulser not operating) was immediately followed by an experimental period (Fishpulser operating).

This second experimental design was accomplished by constructing a corridor, using a beach seine, directly in the front of the Fishpulser (Figures 1 and 2). The corridor was positioned diagonally across one half on the tank and measured approximately 16.5 m long and 1.5 m wide. The Fishpulser was situated at one end of this corridor. The video camera situated above the Fishpulser was re-adjusted to ensure adequate coverage of the entire corridor. Preliminary analysis of the energy distribution throughout the experimental half of the tank indicated a marked decrease in acoustic signal at approximately 5 m from the Fishpulser. The corridor was subsequently divided into three equal 5 m zones for comparison of fish distribution during and after the operation of the Fishpulser.

Two types of tests were conducted for each of the test sounds, short and long term. Light levels during these tests were kept at a minimum as walleye are very sensitive to light (Patrick 1984).

2.4.1 Short-term Response Tests

Short term tests (10) during which the Fishpulser (Plate 1) operated for five minutes, were conducted to determine the initial response of walleye to each sound. Individual tests were separated by a 55-min rest period (no Fishpulsers operating) to allow for the re-distribution of walleye in the corridor.

For each replicate, a minimum of 15 individuals were placed in the corridor. At the end of the 5-min test period, the number of individuals within the first 5 m from the Fishpulser, Zone 1, was tabulated and compared to the number of fish in the remaining two, 5 m zones (Zone 2 and Zone 3). All ten replicates were completed using the same individuals. The effectiveness of the Plate 2 in repelling walleye was also replicated ten times and evaluated in a similar fashion. Initially, the effectiveness of the second sound was also evaluated using the same group of fish. Subsequent tests (10) involved a different group of fish (n = 15) as were involved in the test with Plate 2.

2.4.2 Long-term Response Tests

Long-term tests were conducted to determine whether the test individuals eventually habituate to the signal generated from the Fishpulser. These tests followed the completion of each of the respective short term tests and involved the same individuals.

Long term tests involved operating the Fishpulser continuously for two hours. The distribution of walleye within the corridor during this period was continuously monitored using a video recorder. The distribution of walleye during the operation of the Fishpulser was compared to a similar control period (Fishpulser not operating).

2.4.3 Additional Tests

The effectiveness of sound in repelling walleye was contrasted to the use of a known repellent - light (Patrick 1984). The effectiveness of either sound or light was simultaneously compared by operating the Fishpulser at one end of the corridor while the opposite end of the corridor, Zone 3, was illuminated by suspending a light (incandescent) from the ceiling. This light was positioned to effectively illuminate the 5 m area. Light levels at the centre of this zone averaged 30 lux. Zone 2 served as a refuge area since this zone was neither appreciably illuminated, less than 10 lux, nor greatly influenced by the Fishpulser illumination in Zone 1, also less than 10 lux.

The distribution of walleye during these tests was visually observed and recorded since it was too dark to videotape the presence/absence of individuals in Zones 1 and 2. The distribution of fish in all three zones was monitored for 2-min prior to the operation of the Fishpulser and the illumination of Zone 3. Zone 3 was illuminated for 2-min prior to the operation of the Fishpulser. At the end of the 2-min period, the Fishpulser (Plate 2) was turned on and allowed to operated for 5 min. Zone 3 was illuminated for an additional 2 min after the Fishpulser was shut off. The

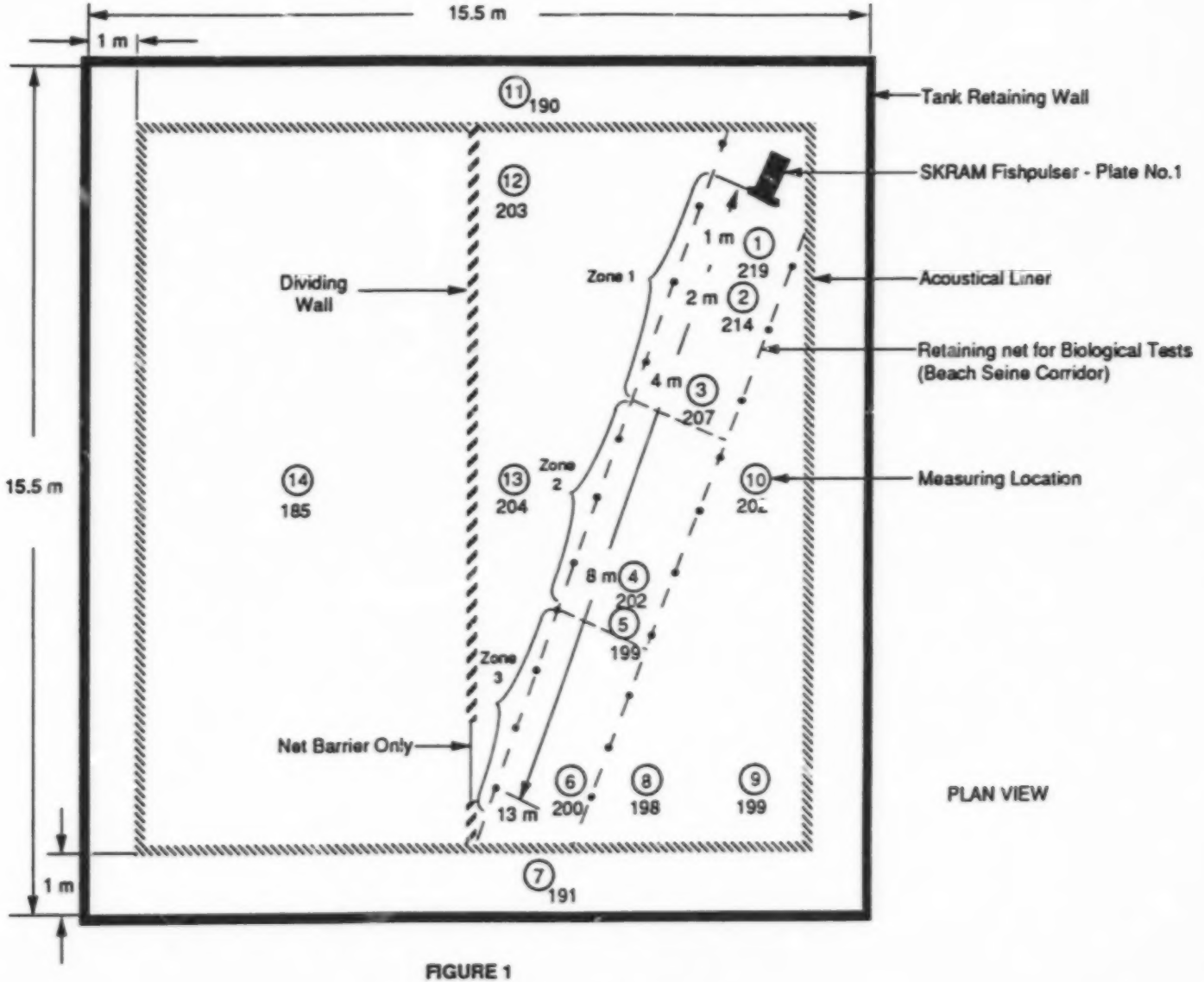

FIGURE 1

HYDROACOUSTIC MEASUREMENT RESULTS WITH PLATE NO.1
- AVERAGED PEAK PRESSURE LEVELS, OVERALL, dB LINEAR re 1 µPa

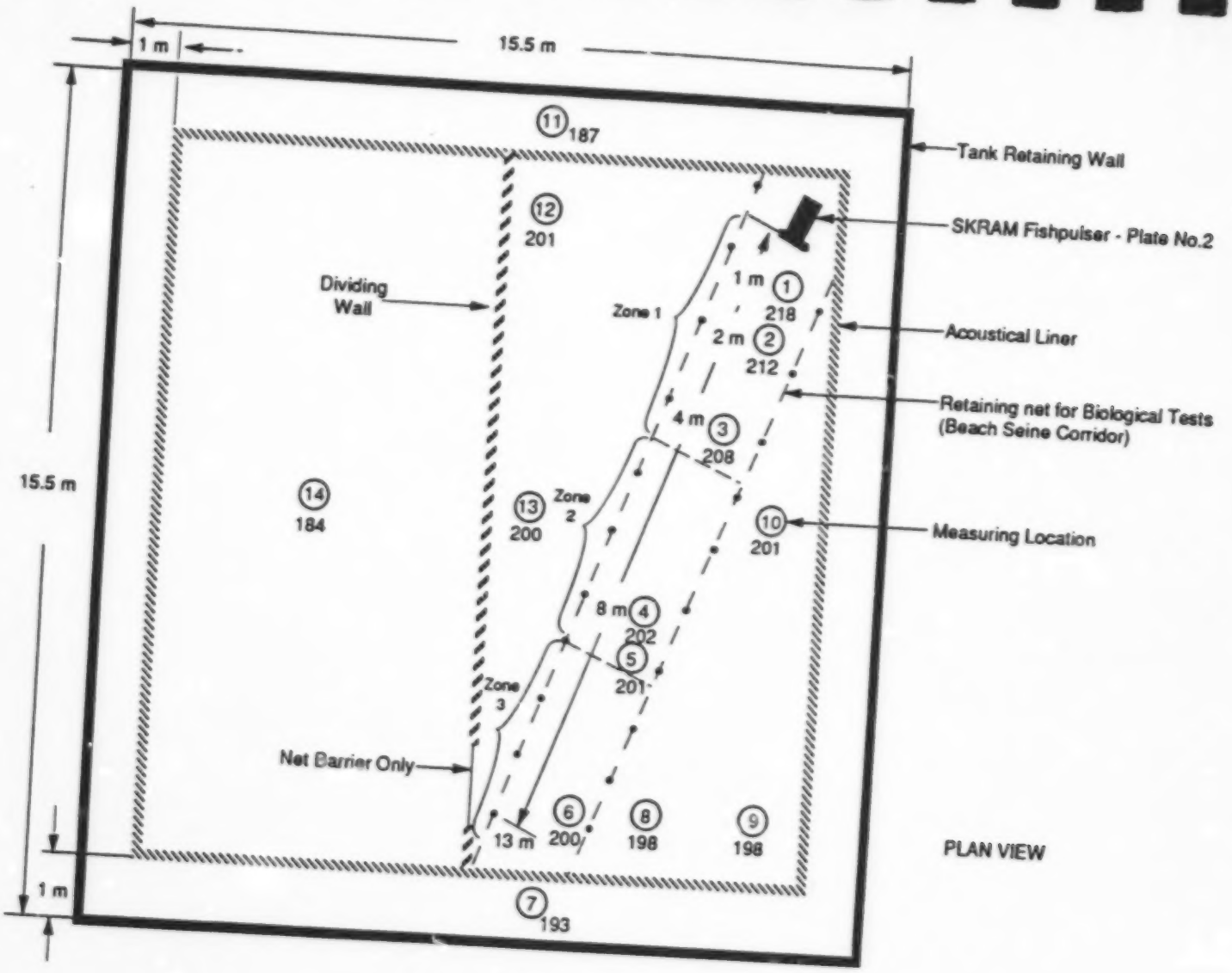

FIGURE 2

HYDROACOUSTIC MEASUREMENT RESULTS WITH PLATE NO.2
- AVERAGED PEAK PRESSURE LEVELS, OVERALL, dB LINEAR re 1 μPa

entire procedure was duplicated.

2.5 Data Analysis

Analysis of the initial response tests involved comparing the number of individuals present during the experimental (Fishpulser operating for 5 min and control period (55 min - Fishpulser not operating) in the area immediately adjacent to the Fishpulser (Zone 1). The ability of the Fishpulser to continuously repel walleye was determined by calculating the percent reduction in the number of individuals in Zone 1 at 5-min intervals over the entire 2-hr test period. The per cent reduction in fish was defined as the following:

$$\frac{C - E}{C} \times 100\% = EI \text{ (effectiveness index)}$$

where C is the number of fish observed during the control period and E is the number of fish observed at five minute intervals during the operation of the Fishpulser.

The simultaneous comparison of both sound and light as deterrents involved contrasting the per cent reduction in walleye between the area influenced to the greatest extent by the Fishpulser (Zone 1) and the opposite, but illuminated end of the corridor (Zone 3). The area in between the two experimental zones served as a refuge area (Zone 2).

2.6 Hydroacoustical Measurements

Sound pressure levels produced by the Fishpulser in the tank were measured and analyzed in order to determine more precisely the acoustical characteristics presented to the fish in these experiments. The acoustical analysis was also used for verifying the correct operation of the Fishpulser (before and after a series of biological tests).

The instrumentation used included two B & K hydrophones, a DAT sound recorder and a B & K 2231 precision sound level meter. The recorded data was later analyzed using a Norwegian Electronics 830 spectrum analyzer and a B & K 2317 RMS-level recorder.

The hydrophones were installed in various locations in the tank to a constant depth of 1 m.

3.0 RESULTS AND DISCUSSION

3.1 Short and Long-Term Response Tests

The initial response of walleye to the two sound stimuli was dissimilar. Individuals responded immediately to the Plate 1 and consistently avoided the area (Zone 1) immediately in front of the Fishpulser. Over the ten replicates, less than seven percent of the total number of individuals ($\bar{x}$ = 0.75 SD $\pm$0.83) present in the entire corridor entered Zone 1 during the

operation of the Fishpulser (Figure 3). These few individuals were positioned to the immediate right or left of the Fishpulser. In contrast, the same individuals exposed to Plate 1 were not observed to immediately flee Zone 1 once the Fishpulser had been outfitted with Plate 2. Further evaluation of this thinner plate using individuals not previously exposed to the Fishpulser yielded similar results. The effectiveness of the sound produced by Plate 2 in repelling walleye varied considerably and ranged from less than 50 to 100% ($\bar{x}$ = 3.87 SD$\pm$3.66) (Figure 4).

The ability of the Fishpulser to serve as a reliable long-term deterrent to the movement of walleye was more evident if the Fishpulser had been outfitted with the Plate 1. During these tests, walleye did not habituate to the sonic signal and consistently avoided Zone 1 for the entire test period (Figure 5). The few individuals that were present in Zone 1 during the initial test period had previously positioned themselves underneath or to either side of the Fishpulser before the test began.

During the second set of long term tests, using Plate 2, results indicated that on at least two occasions during the 2-hr period the majority of walleye were present in Zone 1 (Figure 5). These fish were not startled by the operation of the Fishpulser.

Overall, these results confirmed that the response of walleye is related to sound spectrum. The sound spectrum emitted by the Fishpulser using Plate 1 was a more effective deterrent than that of Plate 2. The perception of sound (*i.e.* - frequency) has been shown to be related to the configuration of the fish as well as the shape and size of its swimbladder (Tavolga 1980 and Saenger 1989). Evaluation and consideration of these characteristics may allow for a further fine tuning of the most appropriate sound spectrum for the repulsion of walleye.

3.2 Additional Tests

The simultaneous comparison of sound and light as behavioral deterrents to the movement of walleye indicated that individuals avoided the area affected by the Fishpulser to a greater extent than the illuminated area (Figure 6). Prior to the introduction of a sonic signal, individual walleye actively avoided (<3%) the illuminated area of Zone 3 and moved to Zones 1 and 2. Activation of the Fishpulser resulted in a decrease in the number of individuals in Zone 1 and a subsequent increase in Zones 2 and 3. At the end of 5 min exposure period to the Fishpulser, the number of individuals in Zone 1 had decreased from approximately 55% to less than 3%. Conversely, the number of individuals in the illuminated area, Zone 3, had increased to approximately 22% of the total number of fish in the corridor. Movement of fish into Zones 2 and 3 may have been even greater if the Fishpulser had been outfitted with Plate 1.

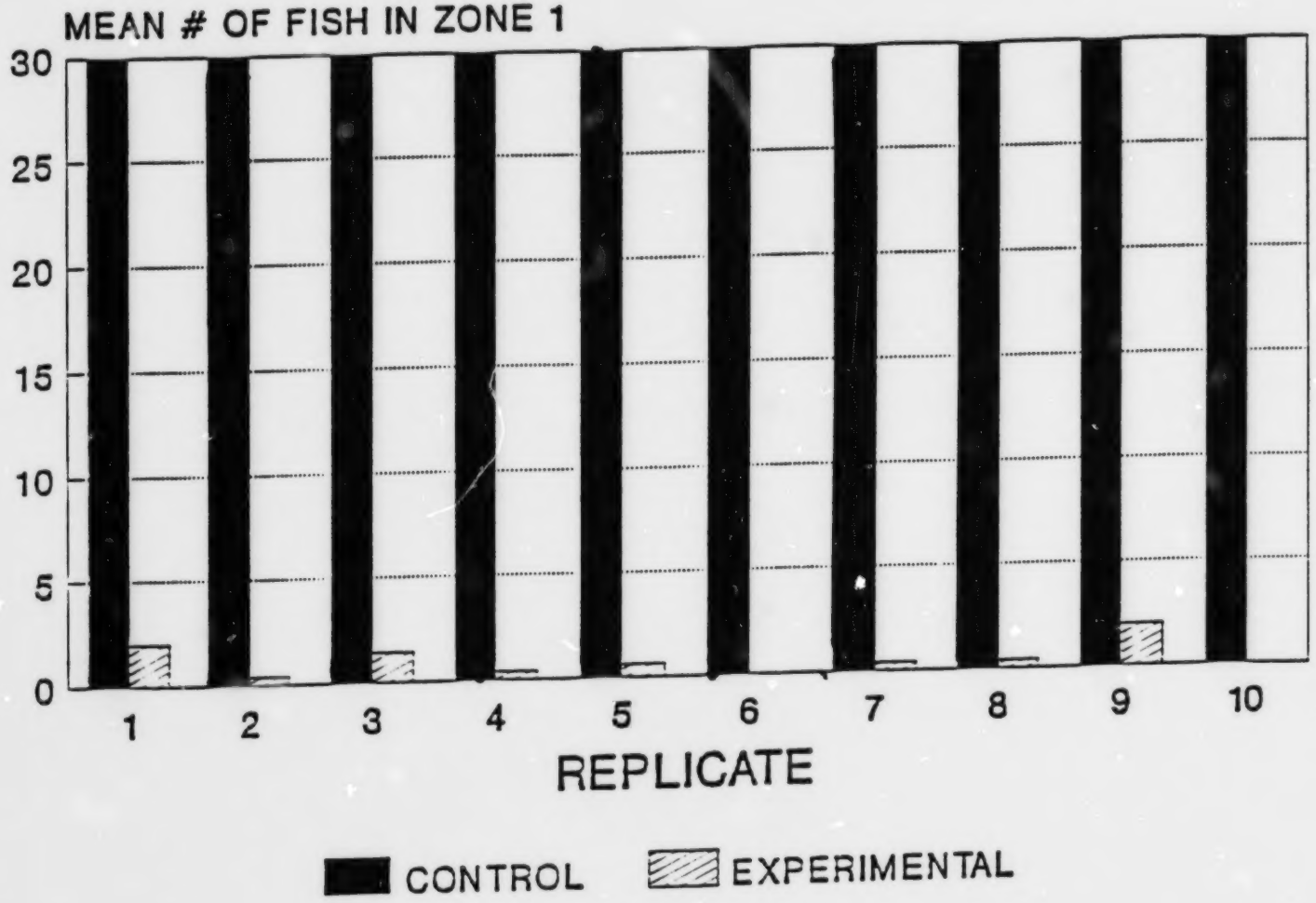

FIGURE 3

Mean number of fish in Zone 1 (5m from the front of the hammer) during control (hammer not operating) and experimental (hammer operating) periods with plate 1. (n = 30)

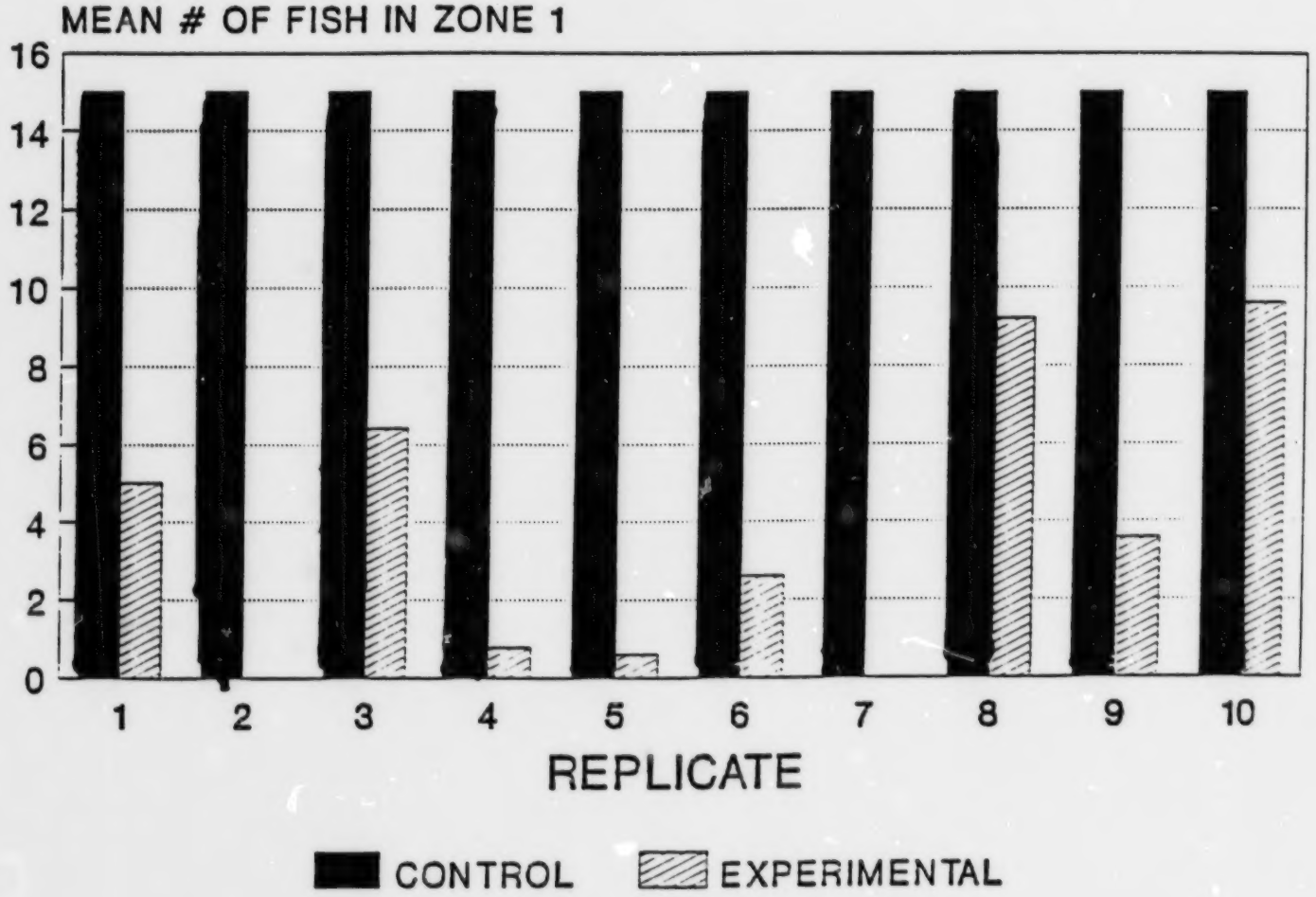

Figure 4
Mean number of fish in Zone 1 (5m from the front of the hammer) during control (hammer not operating) and experimental (hammer operating) periods with plate 2. (n = 15)

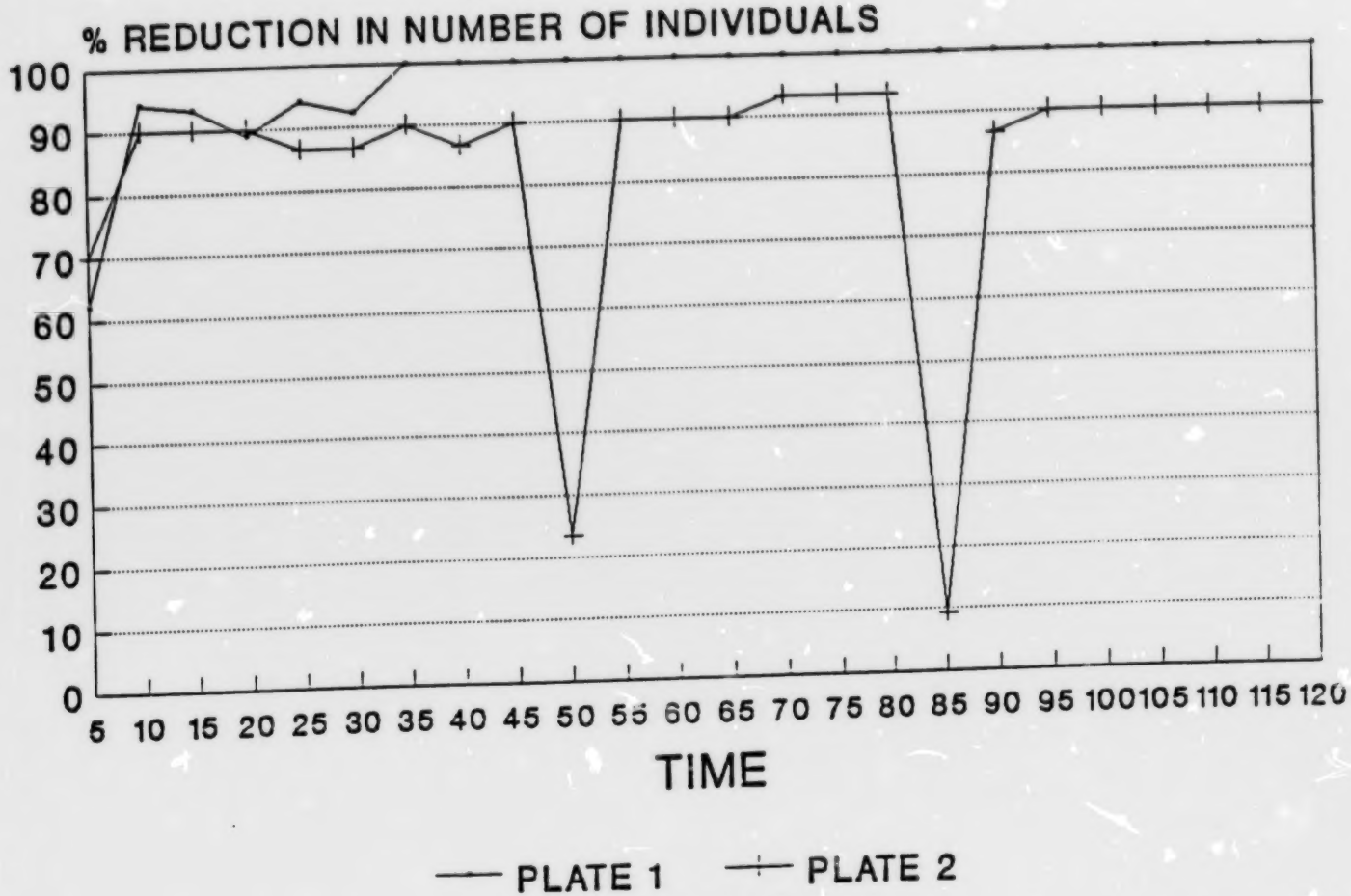

FIGURE 5

The percent reduction in numbers of individuals in Zone 1(5m from the front of the pulser) with time. The pulser was allowed to run continuously for two hours. The percent reduction in fish was calculated at five minute intervals.

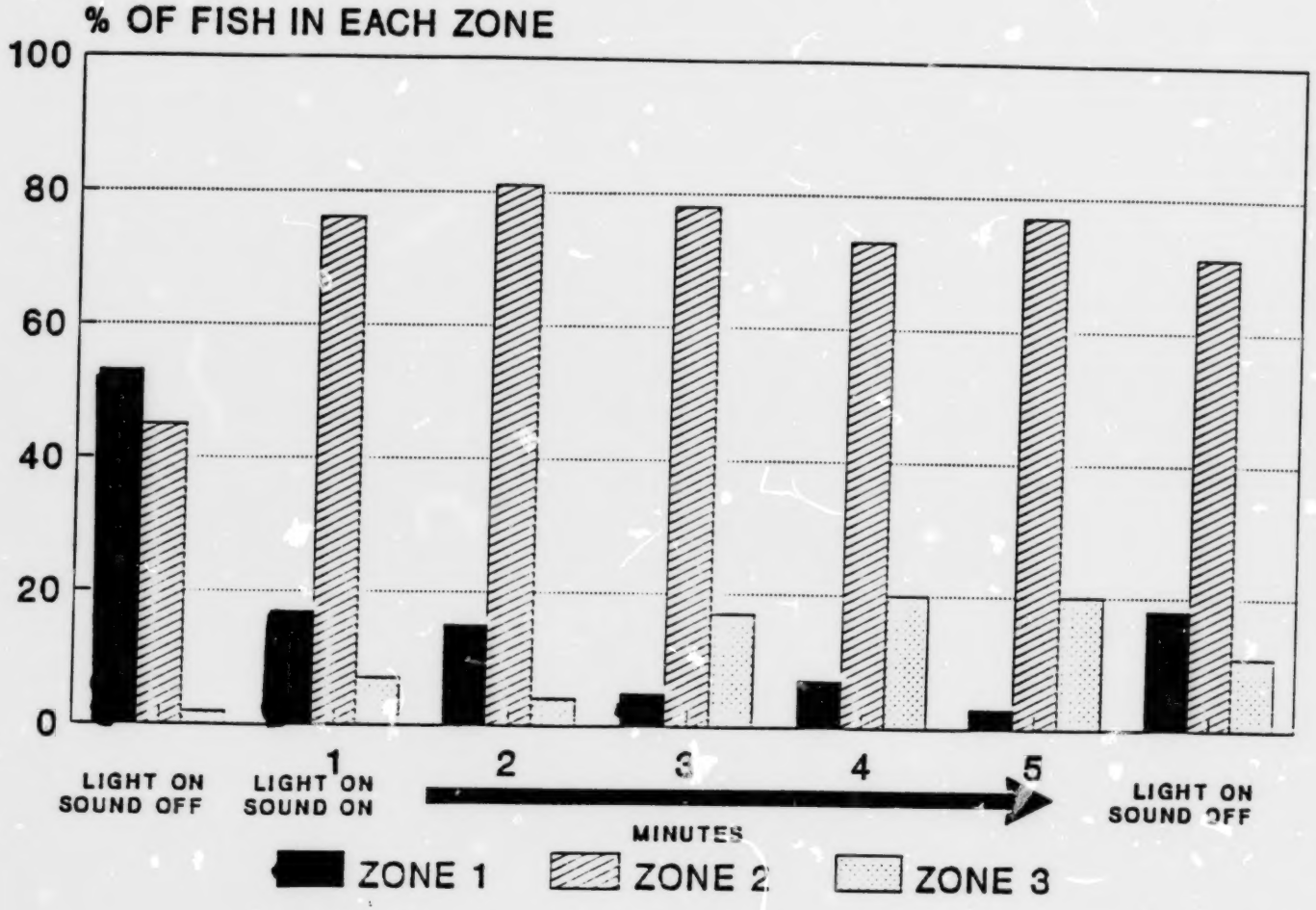

FIGURE 6

This graph depicts the number of individuals found in each zone during various experimental procedures over time. Zone 1 represents a 5 m area directly in front of the pulser, (Plate 2). Zone 2 is a refuge area and Zone 3 represents the illuminated area 5 m from the back wall for the additional tests.

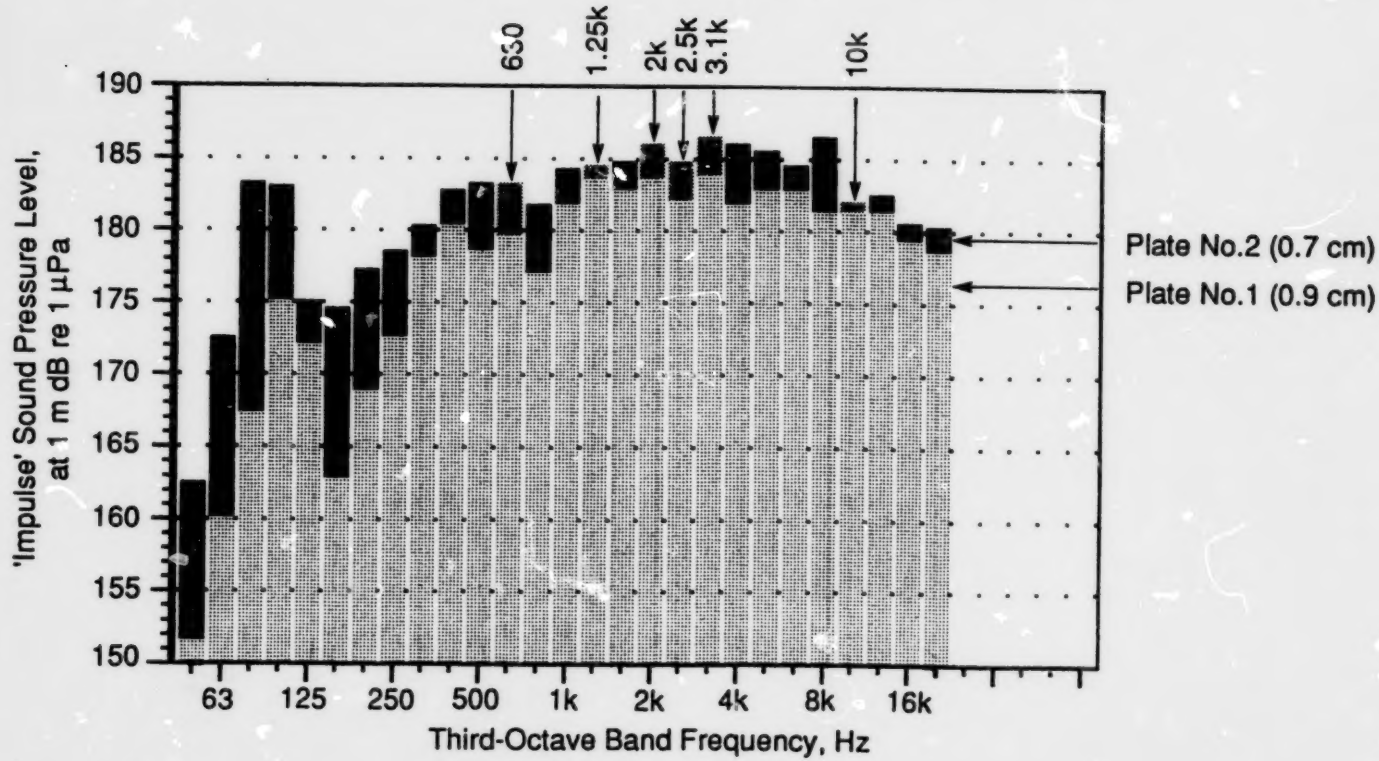

FIGURE 7

SOUND SPECTRA USED IN THE WALLEYE TANK EXPERIMENTS

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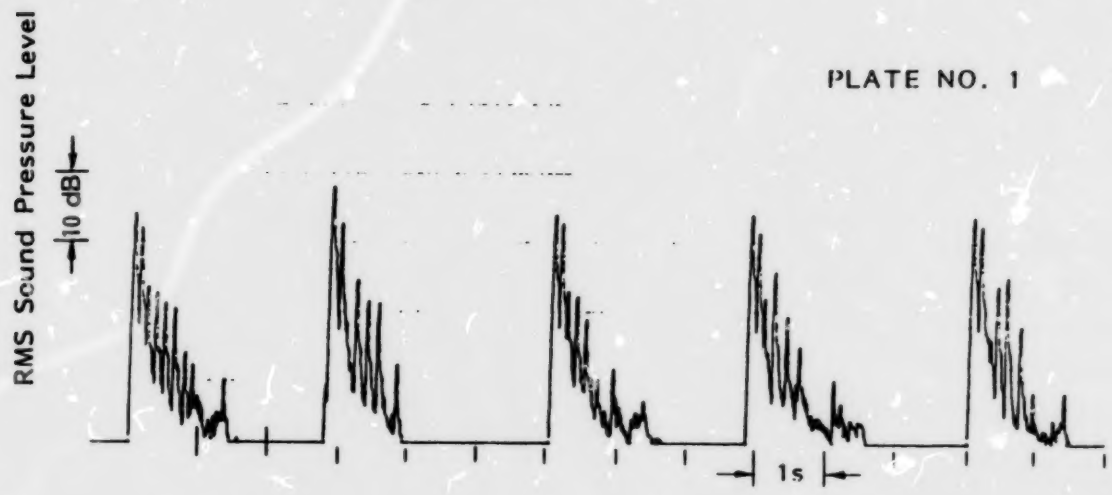

Note: Recorder Time Constant, 16 ms

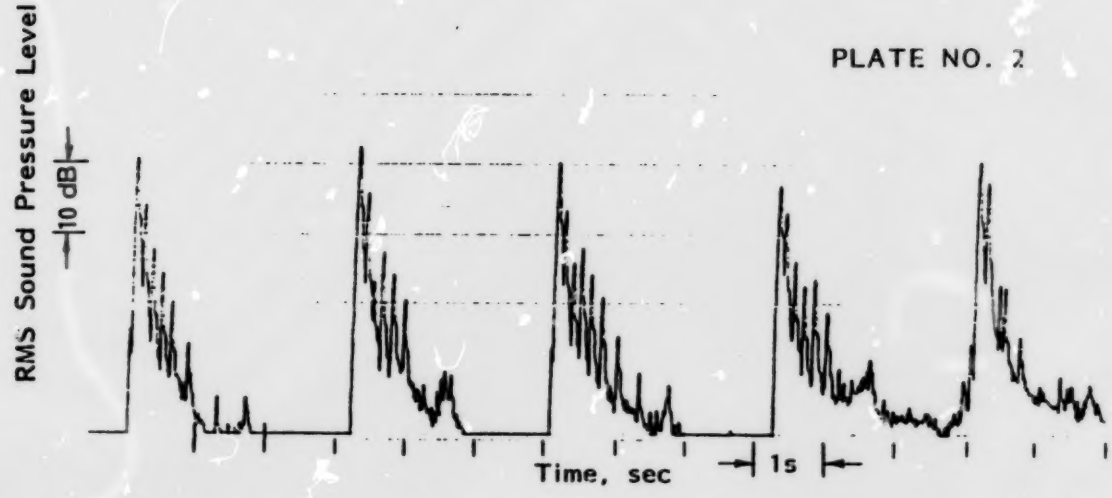

FIGURE 8

SAMPLE TIME HISTORIES OF
SINGLE SKRAM FISHPULSER OPERATING IN TEST TANK

3.3 Acoustical Analysis

A summary of the averaged, peak pressure levels produced by the two test sounds from the Fishpulser at various locations in the tank are shown in Figures 1 and 2. The sound gradient, or decay with distance, from Zones 1 to 2 was close to free field (*i.e.* 5 dB/distance doubling). From Zones 2 to 3 there was little gradient due to reverberation within the tank. This appears to be consistent with the movement patterns of the walleye observed in the tank. That is, avoiding Zone 1 in which the sound gradient was the greatest. In more open water, however, the sound gradient will extent further from the source and the walleye could be expected to move beyond Zone 2 in the tank.

Figure 7 shows the two sound spectra that were used in these experiments. Both sound were similar except that the spectrum generated by Plate 1 had higher sound levels at some of the mid-frequencies, particularly at 630 Hz. Plate 2 generated greater sound levels mainly at low frequencies.

Figure 8 illustrates the temporal patterns produced by the single Fishpulser in these experiments. With either plate, the initial impulse was followed by several decaying repetitions spaced about 130 ms apart.

4.0 SUMMARY

1. The Fishpulser outfitted with the thicker Plate 1 effectively repelled walleye from a 5 m area. The sound spectrum emitted from the Plate 2 was much less effective than that from Plate 1 within the limits of the experimental tank.

2. Walleye did not habituate to the sonic signal emitted from a single Fishpulser outfitted with Plate 1, being effectively repelled for at least two hours. Plate 2 was significantly less reliable as a long term deterrent than Plate 1 within the confines of the experimental tank.

3. Sound appears to be a stronger deterrent to the movement of walleye than incandescent light.

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